A Content-based Watermarking Scheme based on Clifford Fourier Transform

Maroua Affes[1, 2], Malek Sellami Meziou[1], Yassine Lehiani[2], Marius Preda[2] and Faouzi Ghorbel[1]
[1]*CRISTAL, National School of Computer Sciences, Mannouba campus, Mannouba, Tunisia*
[2]*ARTEMIS, Institute TELECOM/TELECOM SudParis, 9, Charles Fourier, Evry, France*

Keywords: Image Watermarking, Clifford Fourier Transform, Harris Detector, JPEG Compression, Robustness.

Abstract: In this paper, we propose a new watermarking method based on Harris interest points and Fourier Clifford Transform. We employed Harris detector to select robust interest points and to generate some non-overlapped circular interest regions. Each region was transformed into Clifford Fourier domain and the watermark was embedded into the Clifford transform coefficients magnitude. Experimental results show the robustness of the proposed method against JPEG compression.

1 INTRODUCTION

Due to the open environment of the internet, download and distribution of digital media have facilitated the wide use and sharing of digital multimedia content. However, these advantages come with challenging problems for copyright protection of digital property. In order to protect and preserve digital content, many regulatory measures, such as copyright protection, are provided. In this context, watermarking is one of the most prominent protection techniques. Often, watermarking methods are categorized by casting/processing domain, the watermark signal type, and hiding position. In any case, good visual fidelity and robustness of the watermark against common image processing and geometric attacks are essential. Many watermarking approaches have been proposed in the literature. A survey of watermarking techniques can be found in (Potdar et al., 2005). In general, watermarking methods can be classified into two generations (Xiaojun and Ji, 2007), (Potdaret al.,2005): traditional watermarking schemes and host-content based methods.

The first generation can be divided into three kinds:

- Template-based watermarking methods: the template is a repeated structure and it embeds into the image to estimate the geometric distortions and to extract the watermark after reversing the geometric transformation.
- Invariance domain based watermarking methods which embed the watermark in a geometrically invariant domain, such as the Fourier-Mellin domain or log- polar domain. These methods provide rotation, scaling and translation (RST) invariance.
- Moment-based watermarking methods which modify the geometric invariants of the image including ordinary moments, such as Zernike moments.

The second generation is based on host contents (Bas et al., 2002). For example, Kutter, Bhattacharjee and Ebrahimi (1999) claimed that the watermark information can be associated with the image content. The basic idea is to use interest points as Harris corners or Scale-Invariant Feature Transform (SIFT), etc, to determine the interest areas. Same areas may be identified in embedding and extraction processes even after geometric distortions. Lee , Kim and Lee HK. (2006) extracted the image feature points by using SIFT and generated a number of circular patch, the mark is embedded into each patch additively in spatial domain. This method can resist general geometric attacks, but their experimental results show that the watermark similarities are lower than 0.7. Lei-da, Bao-long and Lei (2008) proposed a RST invariant image watermarking scheme using Harris feature points. They extracted Harris feature points to generate circular regions. Then these regions was rotation normalized. This method is robust against

Affes, M., Meziou, M., Lehiani, Y., Preda, M. and Ghorbel, F.
A Content-based Watermarking Scheme based on Clifford Fourier Transform.
DOI: 10.5220/0005748403720378
In *Proceedings of the 11th Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2016) - Volume 3: VISAPP*, pages 374-380
ISBN: 978-989-758-175-5

RST attacks, but it needs inverse normalization, which introduces error to weaken the robustness against common signal operation.

In this paper, we propose a content-based watermarking scheme that uses a Harris feature point detector. The watermark is embedded into frequency domain of interest regions. We will give in section 2 an overview of some frequency watermarking methods. In section 3, Clifford Fourier Transform will be recalled and we will describe the embedding and the extraction process of the watermarking algorithm. Experimental results will be presented in section 4. We will eventually conclude and give some possible perspectives for future work.

2 FREQUENCY WATERMARKING METHODS

The watermark can be embedded directly on pixels or in the image frequency transform coefficients. The most used transforms are Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT) and the well-known Discrete Cosine Transform (DCT).

DCT-based watermarking techniques use the middle-frequency coefficients because the modification of low frequencies affects the visual quality of the image and the modification of high frequencies causes local distortion along the edges (Neeta et al., 2010).

The watermarking in DCT domain was first introduced by Koch and Zhao (1994) by modifying the magnitude of the middle-frequency coefficients. This method shows good robustness to JPEG compression. The image is divided into blocks of size 8x8. After that, some blocs are selected by a specific function and they are transformed to DCT domain. Before the embedding process, for each block, a condition tests two selected mi-frequency coefficients to study the validation of bloc to embed the watermark bit. The criterion for valid blocks is specified by the relationships between the two selected coefficients. This criterion is used in the extraction process to know if the block contains a bit of watermark or not. This method is based on modifying the magnitude of the selected coefficients. To create the watermarked image, for each block, it is required to perform the inverse DCT. The extraction process is very simple and it is a blind procedure. It has the same steps of the embedding process. To estimate the inserted bit, it suffices to read the sign of the difference between the modules of the two selected mi-frequency. Using these constraints, the experimental results indicate that the watermark can, with sufficient noise margins, survive common processing, such as lossy compression.

Discrete wavelet transform find a great popularity in watermarking technique. It supports multi-channels and gives excellent spatial localization. In general, the DWT watermarking scheme consists first in partitioning the cover image into high and low frequency quadrants. The low frequency quadrant is again split too into more parts of high and low frequencies and this process is repeated until the signal has been entirely decomposed. For the first decomposition the DWT gives four resolution levels: LL1, LH1, HL1, and HH1. It is well known that the maximum energy is located in LL sub-band. So, the mark is embedded in some selected coefficients from HL, LH and HH via additive modification. In the detection process, the same steps as the embedding process are repeated. Typically, it consists of a process of correlation estimation (Vaishali and Sachin, 2011). DWT watermarking method is robust against JPEG compression, cropping, median filtering, adding noise and scaling. Unfortunately, this approach has some disadvantages. Computing DWT is more time consuming than computing DCT. Also, it embeds the watermark in an additive way. So, to detect the watermark, it is necessary to correlate the watermarked image coefficients with the initial watermark. Therefore, the image itself must be treated as noise, which makes the detection extremely difficult (Potdar et al., 2005), (Seema et al., 2012).

The DFT domain is also used in watermarking technique because it offers robustness against geometric distortions like cropping translation, rotation, scaling, etc. DFT based watermark embedding techniques can be divided into two kinds. In the first one, the watermark is directly embedded by modifying the DFT amplitude and phase coefficients. In the second case, a template is used to estimate the transformation and resynchronize the image. For example, O'Runaidh, Dowling and Boland (1996) proposed a DFT watermarking algorithm modifying the DFT phase information. Its experimental results show that this technique is robust against image contrast operation and rotation. In (O'Runaidh and Pun, 1998) authors proposed another DFT watermarking technique using log-polar coordinates system. Results show that this scheme is robust against RST attacks. This technique is basically used for greyscale images watermarking. To extend the method, a marginal treatment proposes to perform watermarking for each colour canal independently. On other side, a lot of interest to find another Fourier transform applicable directly on colour images was reported. As example, the Clifford Fourier Transform has been proposed in 2010 as a rigorous solution to overcome the limits of the classical Fourier transform.

3 PROPOSED WATERMARKING SCHEME

In this section, we will first remind the principles of Clifford Fourier transform, which will be used later for our robust watermarking algorithm against JPEG compression.

The classical Fourier transform have been used in many fields such as harmonic analysis and group theory to process 1D signal and greyscale images. On colour images, three Fourier transforms are applied on each channel. To avoid this marginal processing, several authors have proposed to embed the colour space in more pertinent geometric spaces such as quaternions. Sangwine and Ell (2000) defined the Quaternion Fourier Transform (QFT). They considered only two Fourier transforms: for the luminance and chrominance. In the exponential of Fourier coefficients, they replaced the complex *i* by the quaternion. Recently, Batard, Berthier and Saint-Jean (2010) defined another Fourier Transform, called Clifford Fourier transform (CFT), which is mathematically more rigorous. This one clarifies relations between the Fourier transform and the action of the translation group through an action spinor group.

The CFT generalizes the Color QFT (Batard et al., 2010) because it is based on group representations theory and Clifford algebras. A pixel of a colour image can be extended in $\mathbb{R}^1_{4,0}$ algebra (vectors of $\mathbb{R}_{4,0}$) as follows:

$$f(x) = r(x)e_1 + v(x)e_2 + b(x)e_3 + 0e_4 \quad (1)$$

Where $x = (x_1, x_2)$ and r, v and b are respectively the red, green and blue channels pixel with coordinates (x_1, x_2).

The CFT is parameterized by a unit vector B whose expression is as follows :

$$\hat{f}_B(u) = \int_{R_2} e^{\frac{1}{2}<u,x>B} e^{\frac{1}{2}<u,x>I_4B} f(x) e^{-\frac{1}{2}<u,x>B} e^{-\frac{1}{2}<u,x>I_4B} dx \quad (2)$$

where I_4 is the scalar pseudo of $\mathbb{R}_{4,0}$ and B is its unit bi-vector. Within the Clifford algebras, a vector can be decomposed in a parallel part and an orthogonal part depending on the choice of the bi-vector B. Being *f* an image and B a bi-vector, this decomposition is

$$f = fBB^{-1} = (f.B + f \wedge B)B^{-1} = f_{\parallel B} + f_{\perp B} \quad (3)$$

where $f_{\parallel B} = (f.B)B^{-1}$ (resp. $f_{\perp B} = (f \wedge B)B^{-1}$) is the parallel (resp. the orthogonal) projection of *f* on a bi-vector B. The above equation can be rewritten as follows by this decomposition (Batard et al., 2010):

$$\hat{f}_B(u) = \hat{f}_{\parallel B}(u) + \hat{f}_{\perp B}(u) \quad (4)$$

where

$$\hat{f}_{\parallel B}(u) = \int_{R_2} e^{\frac{<u,x>}{2}B} f_{\parallel B}(x) e^{-\frac{<u,x>}{2}B} dx = \int_{R_2} f_{\parallel B}(x) e^{-<u,x>B} dx$$

and

$$\hat{f}_{\perp B}(u) = \int_{R_2} e^{\frac{<u,x>}{2}I_4B} f_{\perp B}(x) e^{-\frac{<u,x>}{2}I_4B} dx = \int_{R_2} f_{\perp B}(x) e^{-<u,x>I_4B} dx$$

We will use decomposition in our proposed schema in order to define the criteria of validity for CFT coefficients to embed the mark.

In order to synchronize the embedded regions and the extracted regions, we used the local Harris features. They provide a potential solution for watermarking to improve the robustness (Papakostas et al., 2011). Also, we chose to embed the watermark in the frequency domain which assures its invisibility and its robustness more than in spatial domain. We used also the CFT to avoid the marginal treatment of colour image which can cause sometimes a false detection of the watermark. CFT is applied on windows of 8x8 around the keypoint. The detailed embedding steps are illustrated in Figure 1. We first transform the colour image to greyscale in order to detect the interest points with Harris detector. We construct the circular locally regions. To avoid overlap between regions (Figure 2a), the Euclidean distance d between the interest points must be upper than the double of patch radius (Figure 2b).

To choose the embedding plane, we set up a small experiment and embed the mark *W* in three

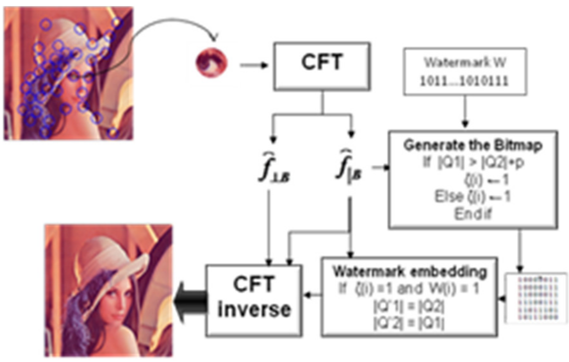

Figure 1: Embedding processes.

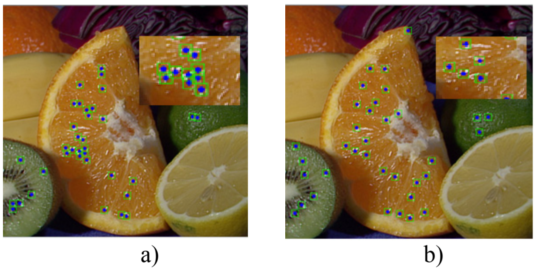

Figure 2: Generation of interest regions (a) overlapped regions, (b) no overlapped regions with Euclidean distance = 20.

different locations: the parallel part $\hat{f}_{\parallel B}$ of CFT, in the orthogonal part $\hat{f}_{\perp B}$ of CFT and in both of them. The results are presented in the following table. To evaluate the three insertion methods, we use the PSNR (Peak Signal Noise Ratio) to measure the imperceptibility of the mark. We note that best results are obtained in the first case.

Table 1: PSNR variation depending on the embedding plane.

Image references \method	$\hat{f}_{\parallel B}$	$\hat{f}_{\perp B}$	$\hat{f}_{\parallel B}$ and $\hat{f}_{\perp B}$
189003	52,67dB	49,67 dB	48,09 dB
295087	53,14 dB	48,92 dB	47,52 dB
42049	53,37 dB	49,46 dB	48,04 dB
299086	52,89 dB	49,13 dB	48,09 dB

We generate a binary random watermark $W = \{w_i, i = 0 \dots N\}$. To know the size of the mark, we construct a bitmap, denoted ξ, which contains "1" if the region $B(i)$ of $\hat{f}_{\parallel B}$ is valid i.e. the region can contain a bit of the mark. The validity of $\hat{f}_{\parallel B}$ is computed as following:

(1) for each region, CFT is applied.

(2) then, two mi-frequency coefficients are selected. To know the possible location of these two coefficients, we study the distribution of coefficients with bases magnitudes values. In this case, we calculate the average of magnitudes of frequency coefficients for multiple windows of 8x8 around the keypoint detected with Harris detector for 30 images. Figure 3 shows the distribution of the amplitudes for both DCT and CFT. We can observe that the lower values of CFT coefficients are shifted to the mi-frequency coefficients when compared with DCT. This observation made us choose the support of potential coefficients where to embed the mark as illustrated in Figure 4.

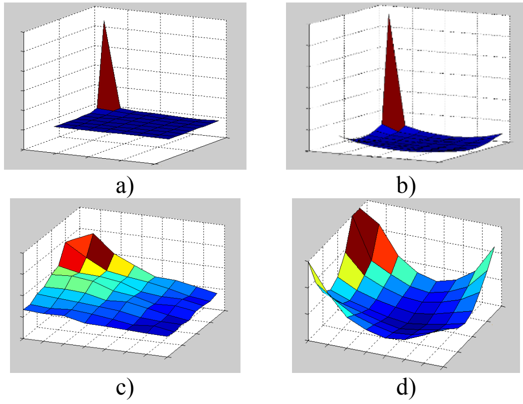

Figure 3: The magnitude of frequency coefficients for DCT (a) and for CFT (b). Image (c) (resp. Image (d)) represents the magnitude of frequency coefficients of DCT (resp. CFT) with the elimination of the DC component.

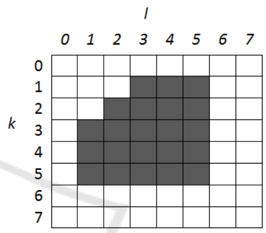

Figure 4: Possible locations for embedding in 8x8 region (shadowed area).

(3) let's denote $|Q(k_i,l_j)|$ and $|Q(k_n,l_m)|$, the two mi-frequency coefficients selected from the shadowed area in Figure 4. We apply the following criteria to choose the coefficients to be permuted:

if $|Q(k_i,l_j)| > |Q(k_n,l_m)|+p$, $\xi(i) \leftarrow 1$ then the region $B(i)$ is valid

else $\xi(i) \leftarrow 0$.

where p is a marginal noise, in the experiment $p = 0.5$. The size of the watermark equals to the number of "1" on bitmap ξ.

(4) error correcting codes are incorporated in watermarking system to overcome the corruption of the watermark in the communication channels. In our method, we use the Hamming code as an error detection system to correct bit error. The watermark is divided into some words, each word contains 4 bits. The Hamming code is then applied to each word to generate (7-4) single bit error correcting code. The use of error-correction codes ensures a better quality signal at the receiver and a higher recovery increases the possibility of the perfect match in embedding process (MacWilliams and Sloane, 1977).

(5) once the robust circular non-overlapping region and the watermark are generated, we start to embed the watermark. Similarly with the Zhao algorithm (Koch and Zhao, 1994), we embed one bit of the watermark in each region. However, we integrate it in the CFT domain. So, for each valid region $B(i)$ (i.e. $\xi(i) = 1$) the following steps are applied:

- CFT is applied
- If W(i) =1
  permute $|Q(k_i,l_j)|$ and $|Q(k_n,l_m)|$:
  $|Q'(k_i,l_j)| = |Q(k_n,l_m)|$ and
  $|Q'(k_n,l_m)| = |Q(k_i,l_j)|$;
- If W(i) =0
  $|Q'(k_i,l_j)| = |Q(k_i,l_j)|$ and
  $|Q'(k_n,l_m)| = |Q(k_n,l_m)|$;
- Inverse CFT is applied

The watermarked image f_w is then obtained by combining the watermarked regions.

The extraction process has the same steps as in embedding process. With Harris detection and the map ξ, we can specify which regions are watermarked. The detailed extraction steps are described in Figure 5. So, for each region if $\xi(i) = 1$ then W' is computed as follow:

$$W' = \begin{cases} 1, & |Q'(k_n,l_m)| > |Q'(k_i,l_j)| \\ 0, & |Q'(k_n,l_m)| < |Q'(k_i,l_j)| \end{cases} \qquad (5)$$

Figure 5: Extraction processes.

4 EXPERIMENTAL RESULTS

Several experiments were performed in order to test the effectiveness of the proposed watermarking method. The visual perceptibility and robustness against compression attacks were tested. Experiments have been conducted on various colour images from the data base of BSD300 (Berkeley Segmentation Dataset 300) as illustrated in Figure 6.

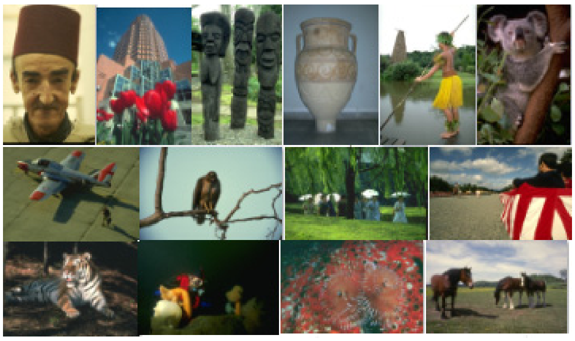

Figure 6: Samples from Berkeley Segmentation Dataset 300.

4.1 Visual perceptibility

The watermarked images were assessed for visual distortion using PSNR. Images in Figure 7 show no visible degradation. For Lena image, the PSNR value is 51.07 dB, for Lion 48.90 dB (ref 108085 in the BSD300). Similar observations were noted for other test images. These PSNR values are all greater than 30.00 dB which is the empirical value for the image without any perceivable degradation (Hsieh and Tesng, 2004).

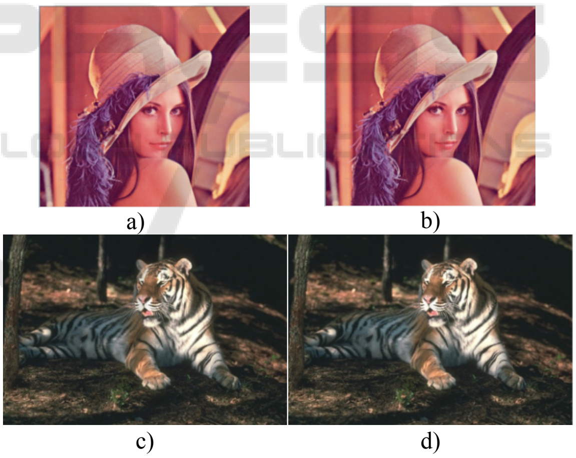

Figure 7: (a) Original and (b) watermarked images at a PSNR value of 51.07 dB for Lena image and (c) original and (d) watermarked image at a PSNR of 48.90 dB for Lion image.

4.2 Robustness to JPEG Compression Attack

The first frequency watermarking method was developed by Koch and Zhao (1994). A modified version of this method was used as a reference to evaluate the robustness of our method against compression attacks. The original Zhao method is applicable on greyscale images and based on DCT domain. We extend it to be applicable on colour image. In fact, we decomposed the RGB image and we applied Zhao method on the red component. An error correction Hamming codes is also used.

To evaluate the robustness of the proposed algorithm, we calculated the Normalized Hamming Similarity NHS:

$$NSH = 1 - \frac{HD(W,W')}{N} \quad (6)$$

where W (resp. W') is the inserted watermark (resp. the extracted watermark) and N is its size.

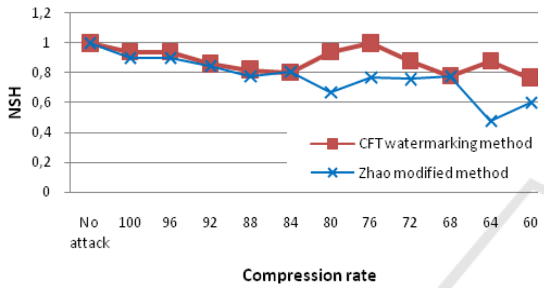

Figure 8: The variation of the NSH depending on the compression rate for the image “Lena” to CFT watermarking method and Zhao modified method.

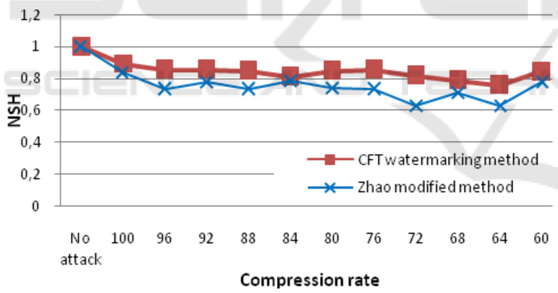

Figure 9: The variation of the NSH depending on the compression rate the image of ref “295087” to CFT watermarking method and Zhao modified method.

For all tests, we chose $|Q(k_i=3,l_j=1)|$ and $|Q(k_n=1,l_m=5)|$ as two mi-frequency coefficients of CFT. They have been modified to carry one bit watermark in each region.

As shown in Figures 8 and 9, our scheme performs better than the modified Zhao method under JPEG compression attack. For example, the NSH for image Lena with quality factor 80% using ECC is 0.94 and 0.61 for Zhao’s method and it is 0,765 with quality factor 60% using ECC instead of 0.6 for Zhao’s method.

5 CONCLUSION

In this paper, we introduced a new method for invisible watermarking based on CFT. The key idea of the proposed algorithm is the combination of generation of the Harris interest regions and colour image watermarking technique. We first used Harris detector to generate circular patch for watermark embedding. Then, we transformed these patches to CFT domain and we selected two mi-frequency coefficients. After that, we inserted the watermark on these selected coefficients by a substitution way. The capacity of the proposed scheme is flexible, since we can manipulate the number of feature points as we want. The experimental results showed that the proposed scheme preserves not only the high perceptual quality, but also the robustness against JPEG compression comparing with Zhao’s method. Future work will be focused on the geometrics attacks.

REFERENCES

Bas P., Chassery J. M. and Macq B., 2002. Toward a content-based watermarking scheme. *Traitement du signal* 2002_volume 19 n°1 2002. p.11-17.

Batard T., Berthier M. and Saint-Jean C., 2010. *Clifford Fourier Transform for Color Image Processing*. In E. Bayro-Corrochano & G. Scheuermann, editeurs, Geometric Algebra Computing in Engineering and Computer Science, chapitre 8, pages 135–161. Springer Verlag, 2010.

Hestenes D. and Sobczyk G., 1987. *Clifford Algebra to Geometric Calculus*. A Unified Language for Mathematics and Physics (Fundamental Theories of Physics). Broché – 31 août 1987.

Hsieh M. S. and Tseng D. C., 2004. Perceptual digital watermarking for image authentication. *Electronic commerce Research*. Volume 4, Issue 1-2 , p.157-170.

Koch E. and Zhao J., 1994. Embedding robust labels into images for copyright protection. *Technical report, Fraunhofer Institut For Computer Graphics*, Darmstadh, Germany. p.242-251.

Kutter M., Bhattacharjee S. K and Ebrahimi T., 1999. Toward second generation watermarking schemes. *In Proceedings of IEEE International Conference Image Processing*, vol. 1, Kobe, Japan. p.320-324

Lee H. Y., Kim H. S. and Lee H. K., 2006. Robust image watermarking using local invariant features. *In Optical Engineering*, 2006. p.037002-037002-11

Lei-da L., Bao-long G. and Lei G., 2008. Rotation, scaling and translation invariant image watermarking using feature points. *In The Journal of China Universities of Posts and Telecommunications*, 2008. p.82-87.

MacWilliams F. J. and Sloane N. J., 1977. *Theory of Error Correcting Codes*. 8, North-Holland, Amsterdam, Netherlands, 1977.

Neeta D., Archana R. and Manthalkar R., 2010. Review of Robust Video Watermarking algorithms. *In International Journal of Computer Science and Information Security*. p. 237-246.

O'Ruanaidh J., Dowling W. J. and Boland F. M., 1996. Phase watermarking of digital images. *In Proc. IEEE Int. Conf. Image Processing*. p. 239-242.

O'Ruanaidh J. and Pun T., 1998. Rotation, scale, and translation invariant digital image watermarking. *In Signal Processing*. p.303-317.

Papakostas G. A., Tsougenis E.D., Koulouriotis D.E. and Tourassis, V. D., 2011. On the robustness of Harris detector in image watermarking attacks. *In Optics Communications*. p.4394-4407.

Potdar, V. M., Song Han and Chang, E., 2005. A survey of digital image watermarking techniques. *Industrial Informatics, 2005*. INDIN '05. 2005 3rd IEEE International Conference. p.709-716.

Sangwine S. J., and Ell T. A., 2000. *The discrete Fourier transform of a colour image*. In J. M. Blackledge & M. J. Turner, editeurs, Image Processing II : Mathematical Methods, Algorithms and Applications, (Proceedings of Second IMA Conference on Image Processing, De Montfort University, Leicester, UK, September 1998), pages 430–441. Horwood Publishing for Institute of Mathematics and its Applications, 2000.

Seema M., Hitesh G. and Saurabh M., 2012. Survey of Digital Image Watermarking Techniques to achieve Robustness. *In International Journal of Computer Applications*, 2012 by IJCA Volume 45-No 13. p.1-8.

Vaishali J. S. and Sachin R. G., 2011. Literature Review of Wavelet Based Digital Image Watermarking Techniques. *In International Journal of Computer Applications*. p.28-35.

Xiaojun Q. and Ji Q., 2007, A robust content-based digital image Watermarking scheme. *Signal Processing* Volume 87, Issue 6, June 2007, P.1264–1280.